Abstract #122, 223rd ECS Meeting, © 2013 The Electrochemical Society

Behavior of a single direct methanol fuel cell in stacks at air maldistribution conditions

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Direct methanol fuel cells (DMFCs) has been considered as one of the most promising power sources for portable applications due to its unique features such as high energy density of methanol, facile fuel storage, fast refueling capability and simple system structure. Nevertheless, there are still several challenging issues which need to be resolved before DMFCs are ready for widespread commercialization.

Since the voltage of a single DMFC is typically below 0.6 V, DMFCs are usually connected in series and stacked together to meet the power demands of various applications. The increased size, voltage and power of a stack, however, brings several additional issues, among which the maldistribution of air flow through different individual cells is extremely detrimental. Since most fuel cell stacks utilize fully or at least partially parallel flow configurations, even a slight deviation of flow resistance, e.g. formation of water slugs in the channels, can lead to significant variations of air flow within the stack [1]. A great deal of efforts have been made in literature to investigate the issue of flow maldistribution, as reviewed by Wang et al.. [2] It has been revealed that the non-uniformity of air flow rate (AFR) through different cells is exacerbated with the increase of stack size, and this air maldistribution can result in variations of single cell voltages across the stack. In some extreme cases, the voltage of certain cells can even become negative, which seriously affects the performance and durability of the stack.[3] Therefore, individual cell voltages within a stack are usually measured in order to monitor the single cell behavior inside the stack. However, the voltage signals alone cannot give any insight into the internal status of each cell, as voltage variations could be attributed to various reasons besides air maldistribution. Therefore, a deep insight into the fundamental relationship between cell voltage and the AFR is pretty important.

In the present work, we measured the voltages of a single DMFC operating at a constant current density of 20 mA/cm^2 with different AFRs in the cathode. In the meantime, a two dimensional model based on our previous work [4] is developed to explore the detailed behaviors inside the cell at various AFRs. One of the most important features of our model is that we account for hydrogen evolution reaction (HER) not only in the anode but also in the cathode. Fig. 1 shows the experimental and simulation results of cell voltages at various AFRs. It can be seen that the modeling results agree quite well with the experimental data. Meanwhile, it can also be noted that the cell voltage varies significantly with AFR. Two critical points should be addressed in this figure. One is point A, where the cell voltage starts to decrease with AFR. The other is point F, where the voltage approaches zero. It has been found that these two critical points are closely related to the HER either in the anode or in the cathode, as shown in Fig. 2, where the HER rates at various AFRs are plotted. From Figs. 1 and 2 we can note that the onset of HER in the anode is the major reason for the drop of voltage at point A. In the meantime, at point F where the voltage reaches zero, a transition from HER in the anode to HER in the cathode occurs. This HER along with the current and potential distributions at each AFR will be addressed in detail within this work.

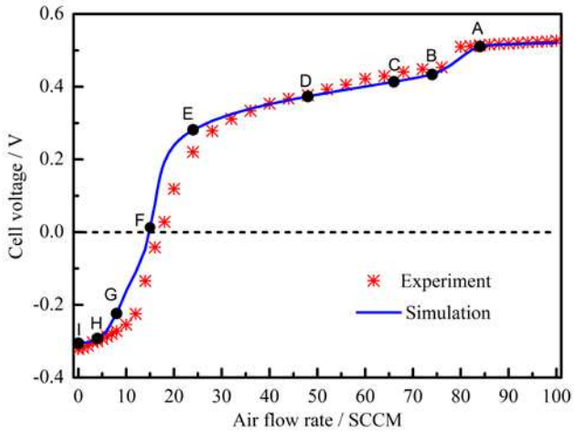

Fig. 1 Experimental and numerical results of cell voltage with AFRs. The cell operates at a constant current density of 20 mA cm^{-2}. The anode is fed with 1M methanol at a flow rate of 1ml min^{-1}, and the operating temperature is 60 °C.

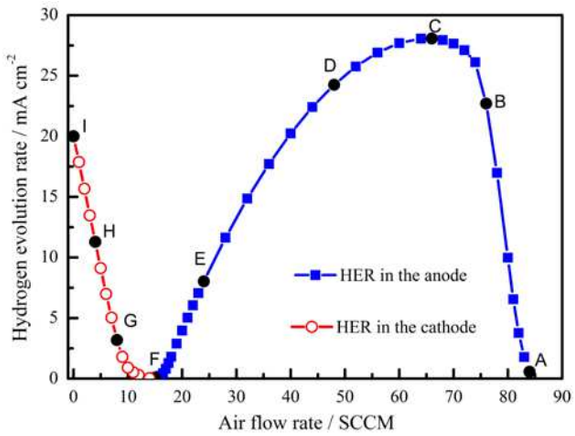

Fig. 2 Hydrogen evolution rate in the anode and in the cathode at various AFRs. The operating condition is the same as in Fig. 1.

References

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